Automating health economic evaluation with R (+GitHub Actions & plumber)

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SheffieldR Users, Sheffield, UK

18th January 2024

DARK PEAK ANALYTICS

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Disclaimer

The views expressed in this presentation are that of the author, and not the affiliated institutions.

Competing interests: R.A.S. Is part of the Scientific Committee for R for HTA, an academic consortium whose main objective is to explore the use of R for cost-effectiveness analysis. P.P.S. and W.M have no competing interests to declare.

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What is Health Economic Evaluation?

"[HTA is] a multidisciplinary process that aims to determine the value of a health technology and to inform guidance on how these technologies can be used in health systems around the world."

World Health Organisation

"The term health economic evaluation describes the comparative assessment of costs and outcomes of alternative health care technologies or health strategies"

Hessel, F. (2008)

What's this got to do with automation?

PharmacoEconomics (2023) 41:227–237
https://doi.org/10.1007/s40273-022-01229-4

LEADING ARTICLE

Living Health Technology Assessment: Issues, Challenges and Opportunities

Praveen Thokala[1] · Tushar Srivastava[1,2] · Robert Smith[1,3] · Shijie Ren[1] · Melanie D. Whittington[4] · Jamie Elvidge[5] · Ruth Wong[1] · Lesley Uttley[1]

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Abstract
Health technology assessments (HTAs) are typically performed as one-off evaluations and can potentially become out-of-date due to the availability of new data, new comparators, or other factors. Recently, living approaches have been applied to systematic reviews and network meta-analyses to enable evidence syntheses to be updated more easily. In this paper, we provide a definition for 'Living HTA' where such a living approach could be applied to the entire HTA process. Living HTA could involve performing regular or scheduled updates using a traditional manual approach, or indeed in a semi-automated manner leveraging recent technological innovations that automate parts of the HTA process. The practical implementation of living HTA using both approaches (i.e., manual approach and using semi-automation) is described along with the likely issues and challenges with planning and implementing a living HTA process. The time, resources and additional considerations outlined may prohibit living HTA from becoming the norm for every evaluation; however, scenarios where living HTA would be particularly beneficial are discussed.

Key Points for Decision Makers

Health technology assessments (HTAs) are typically performed as one-off evaluations and can quickly become out-of-date.

Living HTA approaches can ensure that the HTAs are up-to-date, and potentially living HTAs could be updated manually or (semi-)automatically using innovative software platforms.

However, living HTA involves substantial time, planning and resource commitments, and as such should only be used in situations where it is important to ensure the HTA is up-to-date.

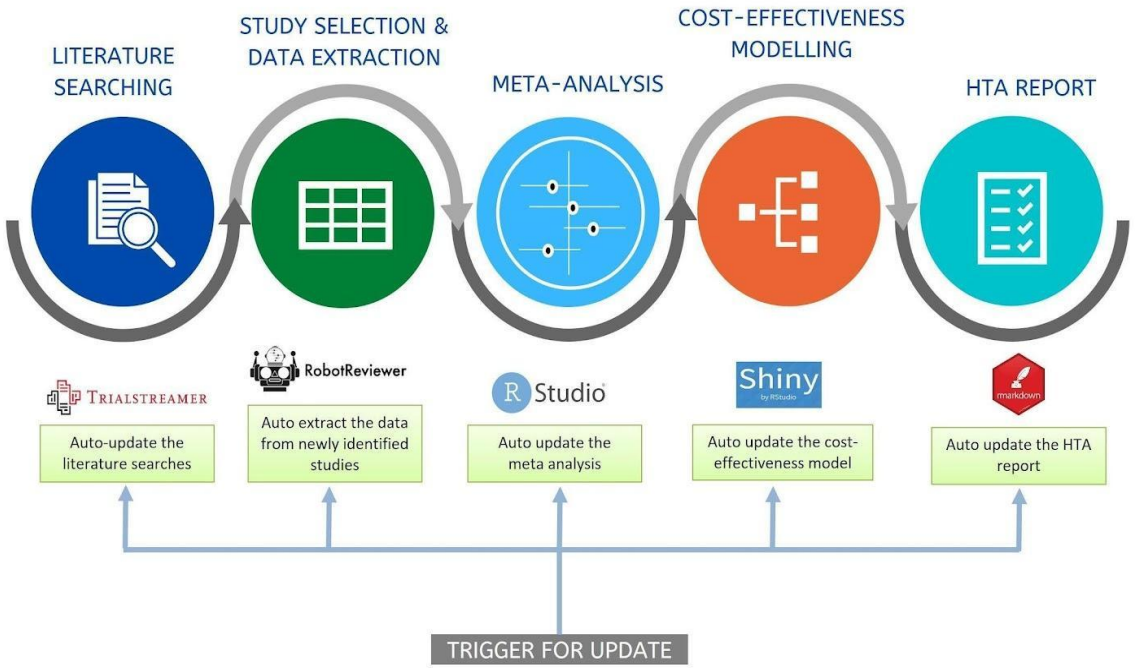
1 Introduction

Health technology assessment (HTA) agencies perform evaluation of clinical and cost-effectiveness evidence of new interventions to decide whether they should be reimbursed. These are typically performed as one-off evaluations and can potentially become out-of-date due to various reasons (e.g., availability of new data, new comparators, new methods, etc.). While some HTA agencies perform updates of HTAs periodically if certain criteria are met, these updates are typically a few years apart and the results of updates may already be out-of-date by the time of the publication.

There is growing recognition of the need for the HTA process to respond to an evolving evidence base, particularly in reimbursement decisions with high uncertainty. A recent paper on 'Life-cycle HTA' suggests that HTA must explore the value of health technologies from inception through maturity, and proposes a model for integrating changes arising from new evidence to feed into adoption, no adoption and disinvestment decisions [1]. However, as far as we know, there is no literature on the practicalities of performing a responsive, dynamic HTA (which we call 'Living HTA').

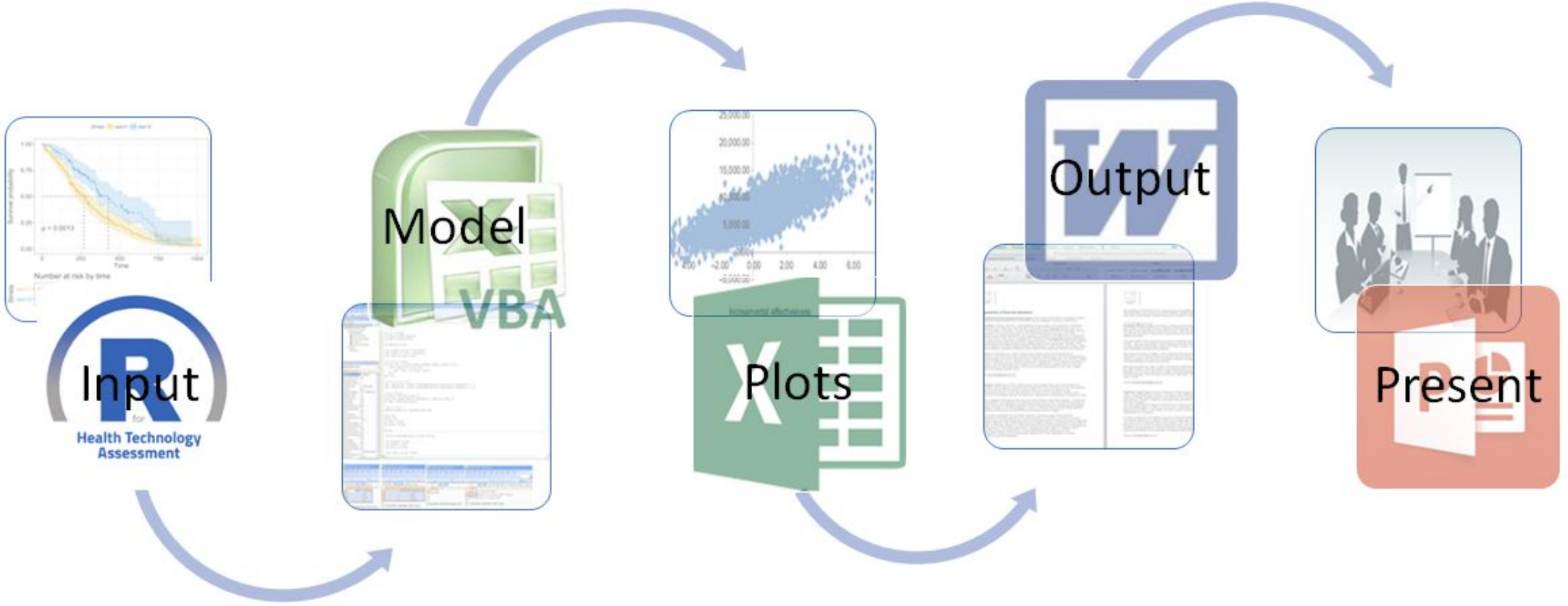
While examples of living systematic reviews and living meta-analyses are already well established, living HTA is not yet fully defined or understood. In this paper, we outline the ways in which the different parts of HTA can become out-of-date, and provide a definition for living HTA and the situations in which it could be useful. While there are similarities between living HTA and the updates that HTA groups make, we outline how the living HTA process could potentially be operationalised from the outset, provide

Extended author information available on the last page of the article

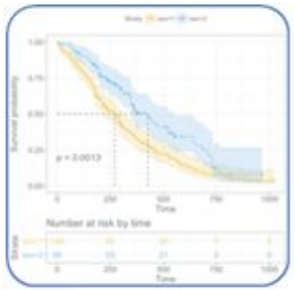


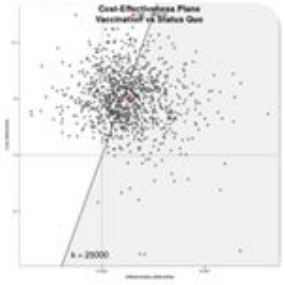
Thokala, P., Srivastava, T., Smith, R., Ren, S., Whittington, M. D., Elvidge, J., ... & Uttley, L. (2023). Living health technology assessment: issues, challenges and opportunities. PharmacoEconomics, 41(3), 227-237.

Current process for health economic models



Future process for health economic models





https://r-hta.org/

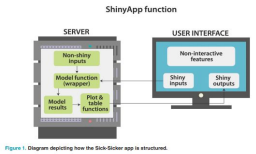
Previous R related publications

2020 2021 2022 2023 2024

COVID-chaos

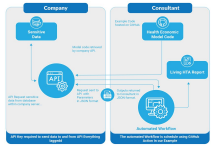
Making Health Economic Models Shiny: A tutorial

Smith RA and **Schneider PP.** Making health economic models Shiny: A tutorial. *Wellcome Open Res* 2020, **5**:69 (https://doi.org/10.12688/wellcomeopenres.15807.2)



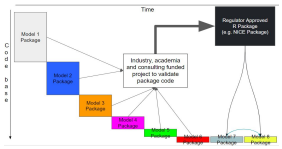
Living HTA: Automating Health Economic Evaluation with R

Smith RA, Schneider PP and **Mohammed W**. Living HTA: Automating Health Economic Evaluation with R. *Wellcome Open Res* 2022, **7**:194 (https://doi.org/10.12688/wellcomeopenres.17933.2)



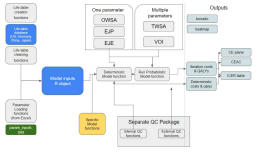
R Packages for health economic evaluation: A tutorial

Smith RA, Schneider PP and **Mohammed W**. R Packages for health economic evaluation: A tutorial. *Wellcome Open Res* 2023. https://doi.org/10.12688/wellcomeopenres.19656.1

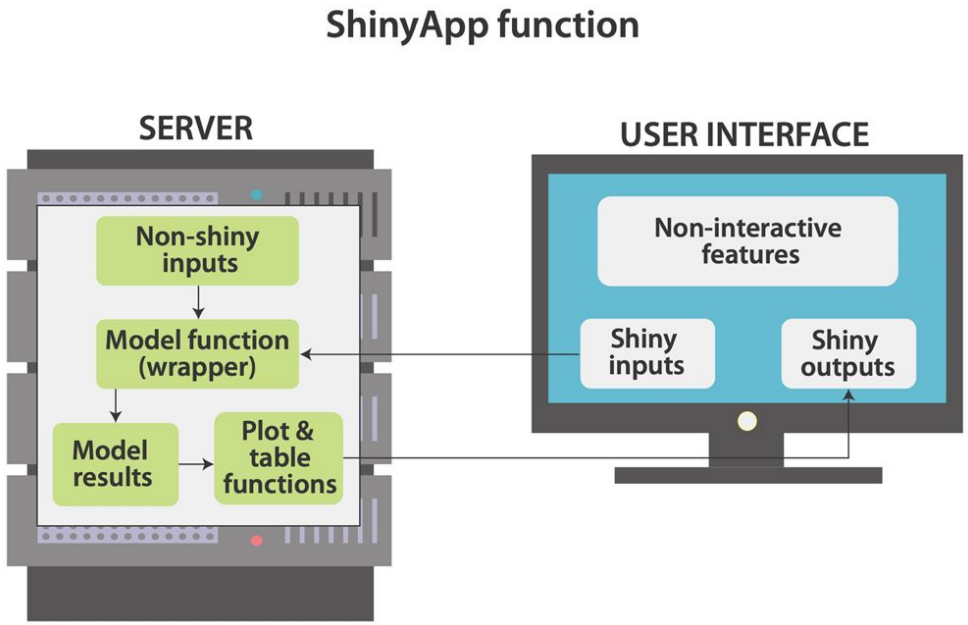


assertHE: an R package to improve quality assurance of HE models

Smith RA, Schneider PP and **Mohammed W**. assertHE: an R package to improve quality assurance of health economic models Submitted to *Wellcome Open Res* 2024.



Making Health Economics Shiny



Wellcome Open Research

METHOD ARTICLE

REVISED **Making health economic models Shiny: A tutorial**

[version 2; peer review: 2 approved]

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Abstract

Health economic evaluation models have traditionally been built in Microsoft Excel, but more sophisticated tools are increasingly being used as model complexity and computational requirements increase. Of all the programming languages, R is most popular amongst health economists because it has a plethora of user created packages and is highly flexible. However, even with an integrated development environment such as R Studio, R lacks a simple point and click user interface and therefore requires some programming ability. This might make the switch from Microsoft Excel to R seem daunting, and it might make it difficult to directly communicate results with decisions makers and other stakeholders.

The R package Shiny has the potential to resolve this limitation. It allows programmers to embed health economic models developed in R into interactive web browser based user interfaces. Users can specify their own assumptions about model parameters and run different scenario analyses, which, in the case of regular a Markov model, can be computed within seconds. This paper provides a tutorial on how to wrap a health economic model built in R into a Shiny application. We use a four-state Markov model developed by the Decision Analysis in R for Technologies in Health (DARTH) group as a case-study to demonstrate main principles and basic functionality.

A more extensive tutorial, all code, and data are provided in a GitHub repository.

Keywords
Health Economics, R, RShiny, Decision Science

Open Peer Review

Approval Status ✓ ✓

	1	2
version 2 (revision) 31 Jul 2020	✓ view	✓ view
version 1 14 Apr 2020	? view	✓ view

1. **Talitha L. Feenstra**, University of Groningen, Groningen, The Netherlands
2. **Yiqiao Xin**, University of Glasgow, Glasgow, UK

Any reports and responses or comments on the article can be found at the end of the article.

App: https://robertasmith.shinyapps.io/sick_sicker/
Paper: https://wellcomeopenresearch.org/articles/5-69
Code: https://github.com/RobertASmith/paper_makeHEshiny
Tutorial: https://r-hta.org/tutorial/markov_models_shiny/

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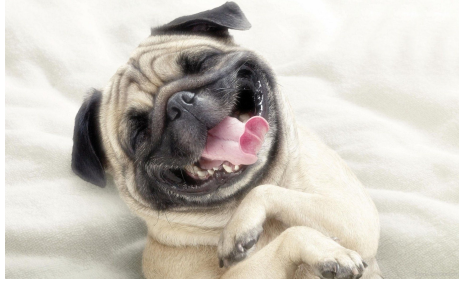
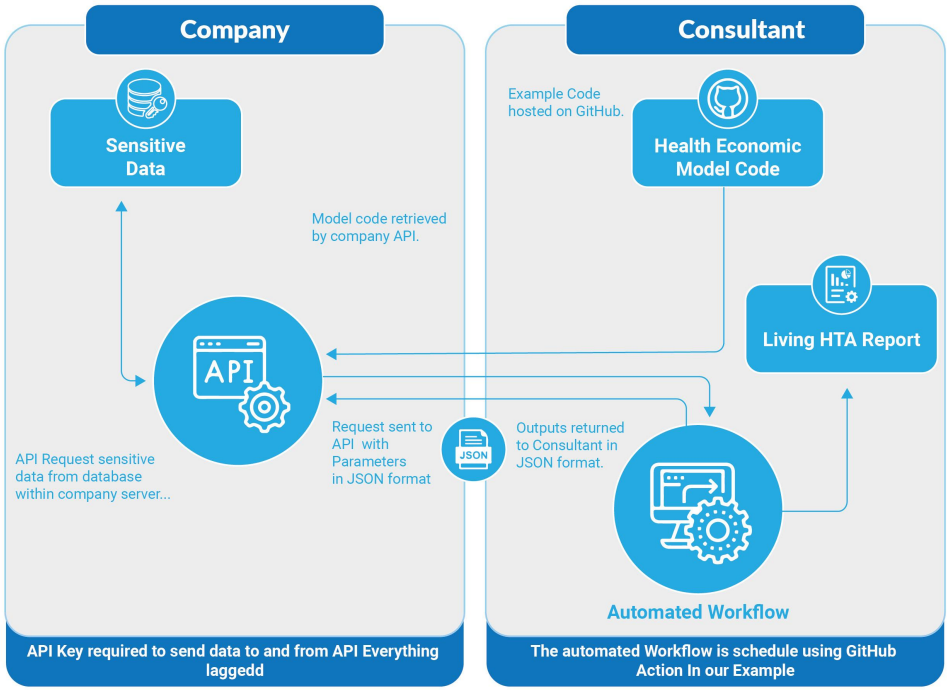
Making Health Economics … hAPpI





Wellcome Open Research

Wellcome Open Research 2022, 7:194 Last updated: 08 AUG 2022

Check for updates

METHOD ARTICLE

Living HTA: Automating Health Technology Assessment with R [version 1; peer review: 1 approved with reservations]

Robert A. Smith[1-3], Paul P. Schneider[1,3], Wael Mohammed[1,3]

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https://doi.org/10.12688/wellcomeopenres.17933.1
Latest published: 21 Jul 2022, **7**:194
https://doi.org/10.12688/wellcomeopenres.17933.1

Abstract

Background: Requiring access to sensitive data can be a significant obstacle for the development of health models in the Health Economics & Outcomes Research (HEOR) setting. We demonstrate how health economic evaluation can be conducted with minimal transfer of data between parties, while automating reporting as new information becomes available.
Methods: We developed an automated analysis and reporting pipeline for health economic modelling and made the source code openly available on a GitHub repository. The pipeline consists of three parts: An economic model is constructed by the consultant using pseudo data. On the data-owner side, an application programming interface (API) is hosted on a server. This API hosts all sensitive data, so that data does not have to be provided to the consultant. An automated workflow is created, which calls the API, retrieves results, and generates a report.
Results: The application of modern data science tools and practices allows analyses of data without the need for direct access – negating the need to send sensitive data. In addition, the entire workflow can be largely automated: the analysis can be scheduled to run at defined time points (e.g. monthly), or when triggered by an event (e.g. an update to the underlying data or model code); results can be generated automatically and then be exported into a report. Documents no longer need to be revised manually.
Conclusions: This example demonstrates that it is possible, within a HEOR setting, to separate the health economic model from the data, and automate the main steps of the analysis pipeline.

Keywords
HEOR, HTA, APIs, R, plumber

Open Peer Review

Approval Status ?

	1
version 1 21 Jul 2022	? view

1. **Mohsen Sadatsafavi**, University of British Columbia, Vancouver, Canada

Any reports and responses or comments on the article can be found at the end of the article.

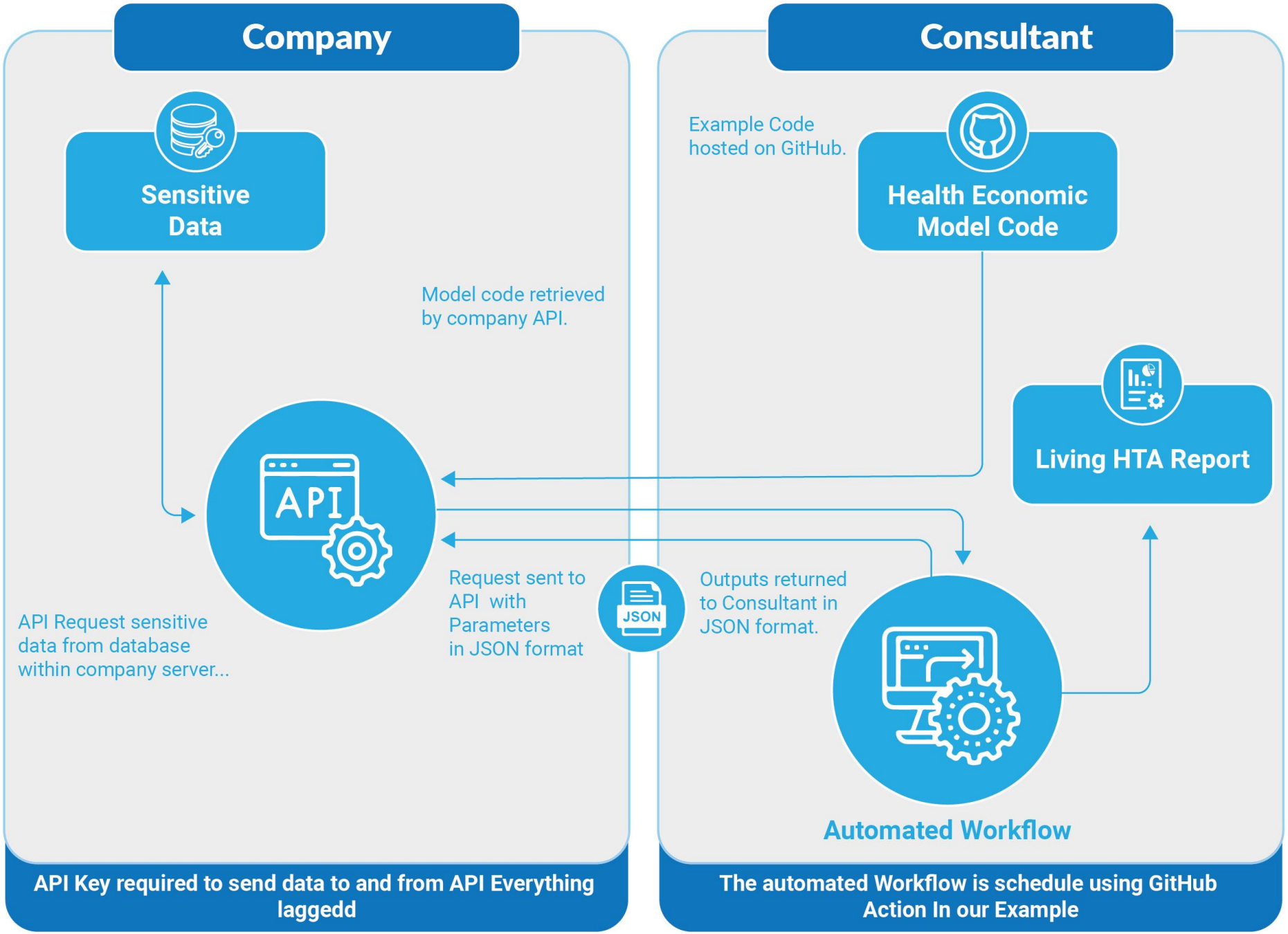
Code: https://github.com/dark-peak-analytics/plumberHE
Paper: https://wellcomeopenresearch.org/articles/7-194
App: https://darkpeakanalytics.shinyapps.io/living_HTA_demo/

University of Sheffield

DARK PEAK ANALYTICS

What I will show today

- GitHub repository containing:
  1. R Script containing a health economic model written in R & C++.
  2. *plumber* script used to generate an API.
  3. *Rmarkdown* document which is used to generate a model report.
  4. R script which uses 1, 2 and 3 to update a report without access to data.
  5. *GitHub actions workflow* which automates this process monthly.
  6. *R-Shiny app* which allows non-technical users to query the API.


Company
Consultant
Sensitive Data
Example Code hosted on GitHub.
Health Economic Model Code
Model code retrieved by company API.
Living HTA Report
API
API Request sensitive data from database within company server...
Request sent to API with Parameters in JSON format
JSON
Outputs returned to Consultant in JSON format.
Automated Workflow
API Key required to send data to and from API Everything laggedd
The automated Workflow is schedule using GitHub Action In our Example

What I will show today

- GitHub repository containing:
  1. R Script containing a health economic model written in R & C++.
  2. ***plumber* script used to generate an API.**
  3. *Rmarkdown* document which is used to generate a model report.
  4. **R script which uses 1, 2 and 3 to update a report without access to data.**
  5. *GitHub actions workflow* which automates this process monthly.
  6. *Shiny app* which allows non-technical users to query the API.

https://github.com/dark-peak-analytics/plumberHE

Hosting a health economic model using plumber

Code chunk 1 - Generating the API

```
1   library(dampack)
2   library(readr)
3   library(assertthat)
4
5   #* @apiTitle Client API hosting sensitive data
6   #*
7   #* @apiDescription This API contains sensitive data, the client does not
8   #* want to share this data but does want a consultant to build a health
9   #* economic model using it, and wants that consultant to be able to run
10  #* the model for various inputs
11  #* (while holding certain inputs fixed and leaving them unknown).
12
13  #* Run the DARTH model
14  #* @serializer csv
15  #* @param path_to_psa_inputs is the path of the csv file containing the PSA parameters
16  #* @param model_functions gives the GitHub repository to source the model code
17  #* @param param_updates gives the replacement values of the editable parameters
18  #* @post /runDARTHmodel
19  function(path_to_psa_inputs = "parameter_distributions.csv",
20           model_functions = paste0("https://raw.githubusercontent.com/",
21                                    "BresMed/plumberHE/main/R/darth_funcs.R"),
22           param_updates = data.frame(
23             parameter = c("p_HS1", "p_S1H"),
24             distribution = c("beta", "beta"),
25             v1 = c(25, 50),
26             v2 = c(150, 70)
27           )) {
28
29
30    # source the model functions from the shared GitHub repo...
31    source(model_functions)
32
33    # read in the csv containing parameter inputs
34    psa_inputs <- as.data.frame(readr::read_csv(path_to_psa_inputs))
35
36    # for each row of the data-frame containing the variables to be changed...
37    for(n in 1:nrow(param_updates)){
38
39    # update parameters from API input
40    psa_inputs <- overwrite_parameter_value(
41                                existing_df = psa_inputs,
42                                parameter = param_updates[n,"parameter"],
43                                distribution = param_updates[n,"distribution"],
44                                v1 = param_updates[n,"v1"],
45                                v2 = param_updates[n,"v2"])
46    }
47
48    # run the model using the single run-model function.
49    results <- run_model(psa_inputs)
50
51    # check that the model results being returned are the correct dimensions
52    # here we expect a single dataframe with 6 columns and 1000 rows
53    assertthat::assert_that(
54      all(dim(x = results) == c(1000, 6)),
55      class(results) == "data.frame",
56      msg = "Dimensions or type of data are incorrect,
57    please check the model code is correct or contact an administrator.
58    This has been logged"
59    )
60
61    # check that no data matching the sensitive csv data is included in the output
62    # searches through the results data-frame for any of the parameter names,
63    # if any exist they will flag a TRUE, therefore we assert that all = F
64    assertthat::assert_that(all(psa_inputs[, 1] %in%
65          as.character(unlist(x = results,
66                              recursive = T)) == F))
67
68    return(results)
69
70  }
```

Load necessary packages

Describe the API, used in Swagger

Roxygen style documentation for function, what are the inputs…

Source the model functions from GitHub

Overwrite default data with non-sensitive inputs

Run the model

Check the results object doesn't contain sensitive data

Return the results object

Schloerke B, Allen J (2022). *plumber: An API Generator for R*. https://www.rplumber.io.

Hosting a health economic model using plumber (1)

```
#* @apiTitle Client API hosting sensitive data
#*
#* @apiDescription This API contains sensitive data, the client does not
#* want to share this data but does want a consultant to build a health
#* economic model using it, and wants that consultant to be able to run
#* the model for various inputs
#* (while holding certain inputs fixed and leaving them unknown).

#* Run the DARTH model
#* @serializer csv
#* @param path_to_psa_inputs is the path of the csv file containing the PSA parameters
#* @param model_functions gives the GitHub repository to source the model code
#* @param param_updates gives the replacement values of the editable parameters
#* @post /runDARTHmodel
function(path_to_psa_inputs = "parameter_distributions.csv",
         model_functions = paste0("https://raw.githubusercontent.com/",
                                  "BresMed/plumberHE/main/R/darth_funcs.R"),
         param_updates = data.frame(
           parameter = c("p_HS1", "p_S1H"),
           distribution = c("beta", "beta"),
           v1 = c(25, 50),
           v2 = c(150, 70)
         )) {
```

Describe the API, used in Swagger

Roxygen style documentation for function, what are the inputs…

Schloerke B, Allen J (2022). *plumber: An API Generator for R*. https://www.rplumber.io.

Hosting a health economic model using plumber (2)

```
30    # source the model functions from the shared GitHub repo...
31    source(model_functions)
32
33    # read in the csv containing parameter inputs
34    psa_inputs <- as.data.frame(readr::read_csv(path_to_psa_inputs))
35
36    # for each row of the data-frame containing the variables to be changed...
37    for(n in 1:nrow(param_updates)){
38
39    # update parameters from API input
40    psa_inputs <- overwrite_parameter_value(
41                            existing_df = psa_inputs,
42                            parameter = param_updates[n,"parameter"],
43                            distribution = param_updates[n,"distribution"],
44                            v1 = param_updates[n,"v1"],
45                            v2 = param_updates[n,"v2"])
46    }
47
```

Source the model functions from GitHub

Overwrite default data with non-sensitive inputs

Schloerke B, Allen J (2022). *plumber: An API Generator for R*. https://www.rplumber.io.

Hosting a health economic model using plumber (3)

```
48    # run the model using the single run-model function.
49    results <- run_model(psa_inputs)
50
51    # check that the model results being returned are the correct dimensions
52    # here we expect a single dataframe with 6 columns and 1000 rows
53    assertthat::assert_that(
54      all(dim(x = results) == c(1000, 6)),
55      class(results) == "data.frame",
56      msg = "Dimensions or type of data are incorrect,
57    please check the model code is correct or contact an administrator.
58    This has been logged"
59    )
60
61    # check that no data matching the sensitive csv data is included in the output
62    # searches through the results data-frame for any of the parameter names,
63    # if any exist they will flag a TRUE, therefore we assert that all = F
64    assertthat::assert_that(all(psa_inputs[, 1] %in%
65          as.character(unlist(x = results,
66                              recursive = T)) == F))
67
68    return(results)
69
70  }
```

Run the model

Check the results object doesn't contain sensitive data

Return the results object

Schloerke B, Allen J (2022). *plumber: An API Generator for R*. https://www.rplumber.io.

Running the model – calling the API

Code chunk 2 - Query the API, retrieve model results and generate report

```r
# remove all existing data from the environment.
rm(list = ls())

library(ggplot2)
library(jsonlite)
library(httr)

# run the model using the connect server API
results <- httr::content(
  httr::POST(
    # the Server URL can also be kept confidential, but will leave here for now
    url = "https://connect.bresmed.com",
    # path for the API within the server URL
    path = "rhta2022/runDARTHmodel",
    # code is passed to the client API from GitHub.
    query = list(model_functions =
                   paste0("https://raw.githubusercontent.com/",
                          "BresMed/plumberHE/main/R/darth_funcs.R")),
    # set of parameters to be changed ...
    # we are allowed to change these but not some others
    body = list(
      param_updates = jsonlite::toJSON(
        data.frame(parameter = c("p_HS1","p_S1R"),
                   distribution = c("beta","beta"),
                   v1 = c(25, 50),
                   v2 = c(150, 100))
      )
    ),
    # we include a key here to access the API here the key is a env variable
    config = httr::add_headers(Authorization = paste0("Key ",
                                                      Sys.getenv("CONNECT_KEY")))
  )
)

# write the results as a csv to the outputs folder...
write.csv(x = results,
          file = "outputs/darth_model_results.csv")

source("report/makeCEAC.R")
source("report/makeCEPlane.R")

# render the markdown document from the report folder,
# passing the results dataframe to the report.
rmarkdown::render(input = "report/darthreport.Rmd",
                  params = list("df_results" = results),
                  output_dir = "outputs")
```

Load necessary packages

Call the API:

- URL and path combine to identify where the API is.
- Query and body both allow for inputs to be provided to the API… We convert the data-frame of inputs to JSON first.
- Config allows us to add the KEY – which is hidden as an environment variable.
- **Result of the API is stored as an object** (results).

Write the results to a csv… not strictly necessary.

Render an Rmarkdown document based on the results of the API call, store the document in ‘outputs’ directory.

Automating health economic model updates with GitHub Actions

Code chunk 3 - Automated report updates

```yaml
on:
  push:
    branches:
    - main
  schedule:
    - cron: '1 1 1 * *'

name: Run DARTH model on client API
jobs:
  createPullRequest:
    runs-on: windows-2019
    env:
      GITHUB_PAT: ${{ secrets.GITHUB_TOKEN }}
  # Load repo and install R
    steps:
    - uses: actions/checkout@master
    - uses: r-lib/actions/setup-r@master

    - name: Setup pandoc
      uses: r-lib/actions/setup-pandoc@v2
      with:
        pandoc-version: '2.17.1.1'

    - name: Install TinyTeX
      uses: r-lib/actions/setup-tinytex@v2
      env:
          # install full prebuilt version
          TINYTEX_INSTALLER: TinyTeX

    - name: Install dependencies
      run: |
          install.packages(
          c("reshape2", "jsonlite", "httr", "readr", "rmarkdown", "markdown")
          )
          install.packages(
          "scales", dependencies = TRUE, repos = 'http://cran.rstudio.com/'
          )
          install.packages(
          "ggplot2", dependencies = TRUE, repos = 'http://cran.rstudio.com/'
          )
      shell: Rscript {0}

    - name: Run the model from API and create report
      env:
         CONNECT_KEY: ${{secrets.PLUMBER_SECRET}}
      run: |
          source("scripts/run_darthAPI.R")
      shell: Rscript {0}

    - name: Create Pull Request
      uses: peter-evans/create-pull-request@v3
      with:
        token: ${{ secrets.GITHUB_TOKEN }}
        commit-message: Automated Model Run from API
        title: 'Living HTA Automated Model Run'
        body: >
          Automated model run
        labels: report, automated pr
```

Schedule jobs based upon a **push to the main branch, or at a scheduled time** (00:01 on 1st of the month).

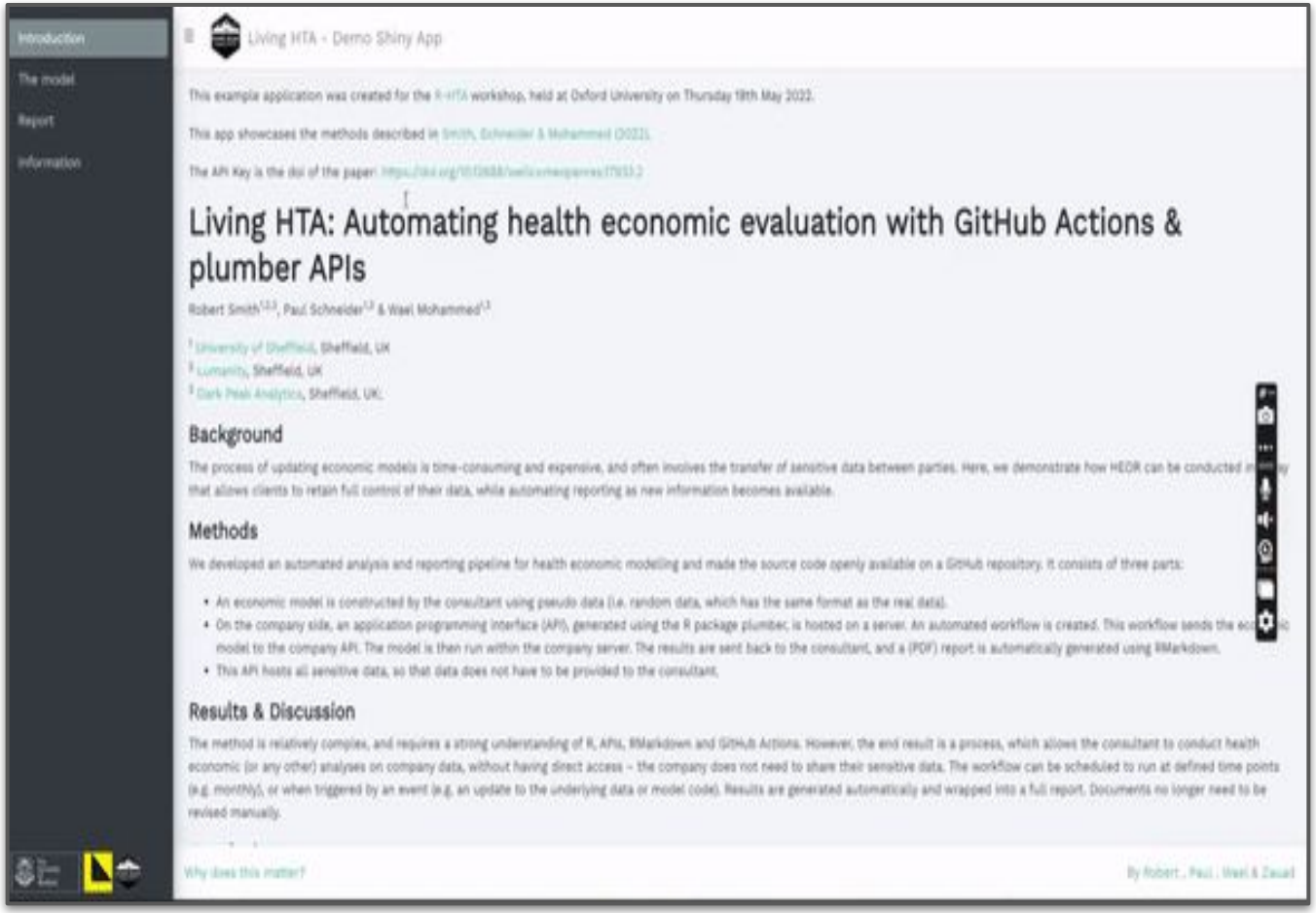
Set-up code:

- Start running a Windows 2019 server.
- Checkout the repository.
- Set up R.
- Install all dependencies

Run the script querying the API and creating a report with Rmarkdown.

Create a pull request to the repository with the new results csv and markdown report included.

R-Shiny app



https://darkpeakanalytics.shinyapps.io/living_HTA_demo/

What are the pros and cons of this framework.

Advantages of this framework

- **Security -** Data owners retain control of their data. No data need leave the data-owner's servers.
- **Transparency -** Separating the model code from the data can significantly improve the transparency of the health economic model. Many models could be passed to the data, not just one!
- **Computational Power** - The computational burden of the model is handled on a remote server.
- **Storage** – Larger datasets can be analyzed than would be possible on a laptop.
- **Living analysis** - API calls can be made at any time. A decision maker can see a report that will always reflect the data held by the company.

Disadvantages of this framework

- **Security -** Likely to remain concerns about data security, even with the authentication procedures built into the API functionality.
- **Transparency -** Risk that running the model remotely will result in the perception that the model is a 'black box' (I'd disagree!).
- **Coding practice -** The model code needs to be versatile enough to manage unknown data updates. *Proper testing will help mitigate these risks.*
- **Technical skillset -** This is not commonly implemented, or a common skill-set among health economists. Most models are not built in R.

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DARK PEAK ANALYTICS

Who can access what?

Stakeholder	Sensitive Data	Model code	Other data
Data Owner (Pharmaceutical company)	☐	☐	☐
External Consultant (Health Economist)	x	☐	☐
3rd Party Consultant (App designer)	x	x	☐

Further resources

More information about this presentation can be found at:

Open-source code: https://github.com/dark-peak-analytics/plumberHE
Open access paper: https://wellcomeopenresearch.org/articles/7-194
Open-access app: https://darkpeakanalytics.shinyapps.io/living_HTA_demo/
R package *plumber*: https://www.rplumber.io
Health economic model code adapted from: https://github.com/DARTH-git

More information about the authors' organizations can be found at:
Dark Peak Analytics
ScHARR, University of Sheffield
Lumanity

The views expressed in this presentation are that of the author and not the institutions…


– Thanks from Sheffield –
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